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Lyman Lake
Apache County, Arizona

National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

Aug 77

PB 281 570

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NATIONAL EUTROPHICATION SURVEY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
LYMAN LAKE
APACHE COUNTY
ARIZONA
EPA REGION IX
WORKING PAPER No. 730

WITH THE COOPERATION OF THE
ARIZONA STATE DEPARTMENT OF HEALTH
AND THE
ARIZONA NATIONAL GUARD
AUGUST, 1977

REPORT ON LYMAN LAKE

APACHE COUNTY, ARIZONA

EPA REGION IX

by

National Eutrophication Survey

Water and Land Quality Branch
Monitoring Operations Division
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Special Studies Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 730

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

August 1977

1a

1b

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Arizona State Department of Health for professional involvement, to the Arizona National Guard for conducting the tributary sampling phase of the Survey, and to those Arizona wastewater treatment plant operators who provided effluent samples and flow data.

The staffs of the Bureau of Water Quality Control, Environmental Health Services, Arizona State Department of Health, and the Arizona Game and Fish Department, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

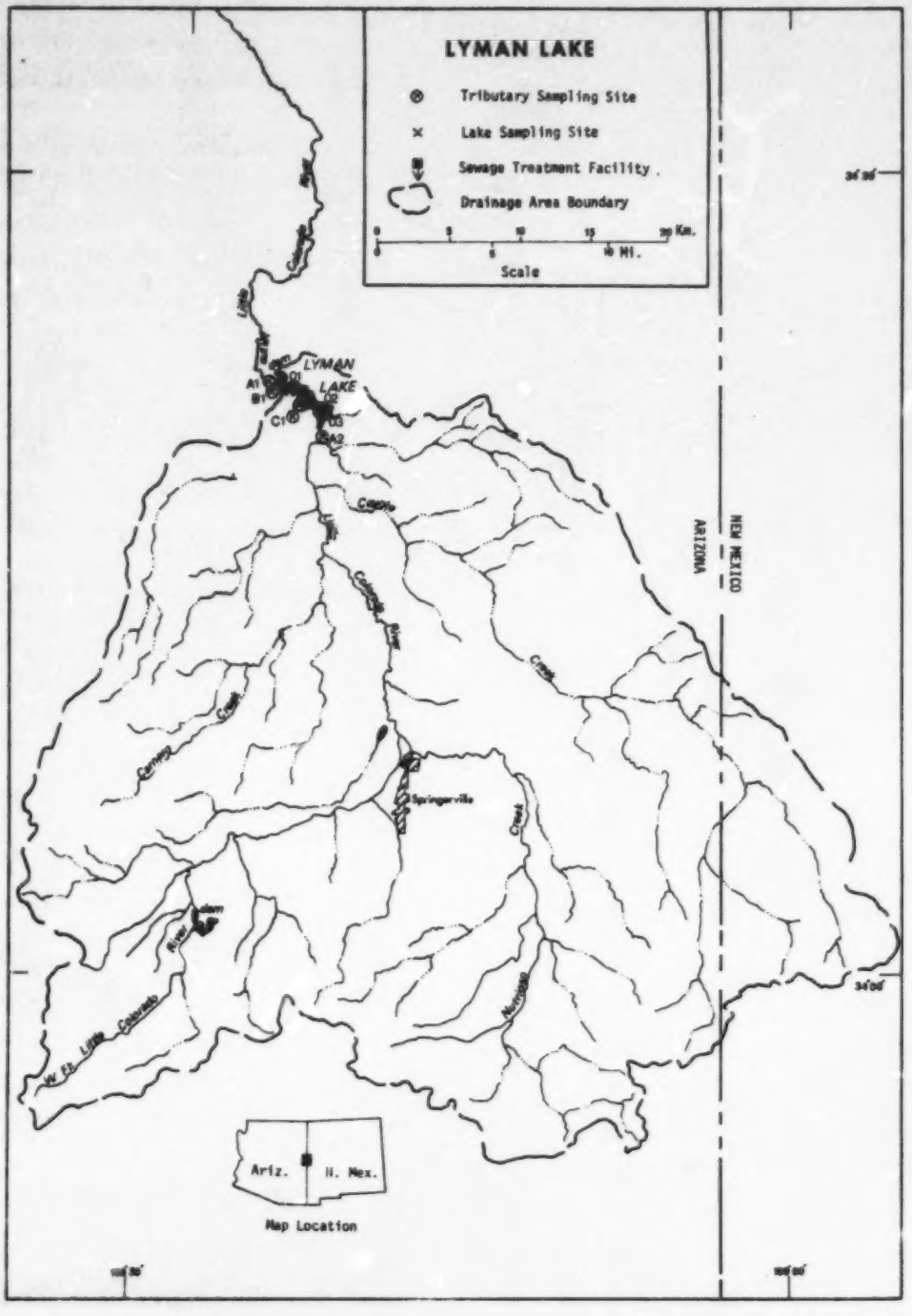
Major General John G. Smith, the Adjutant General of Arizona, and Project Officer Colonel Richard A. Colson, who directed the volunteer efforts of the Arizona National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

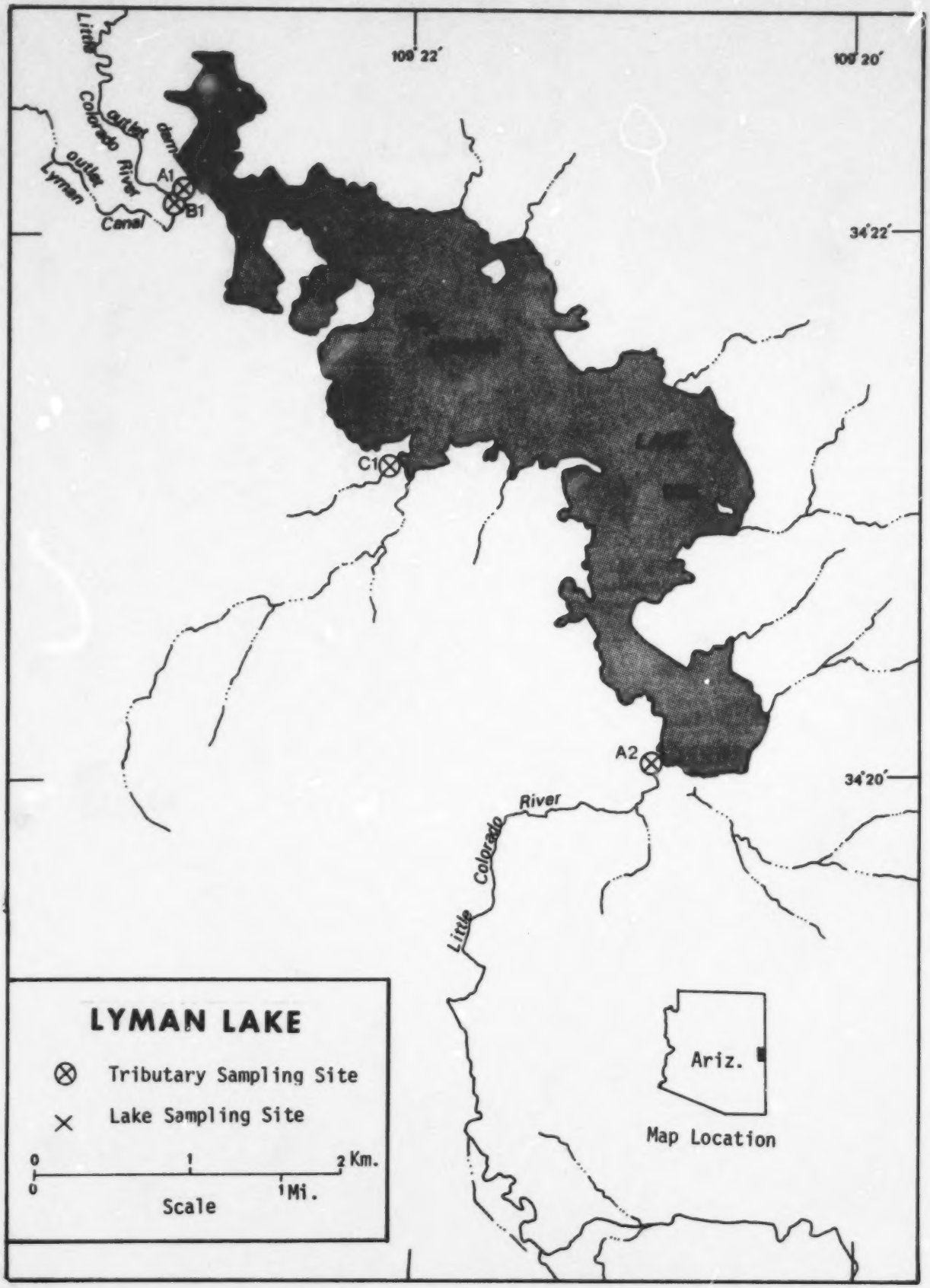
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF ARIZONA

LAKE NAME	COUNTY
Big Lake	Apache
Fools Hollow Lake	Navajo
Lake Havasu	Mohave (San Bernadino in CA)
Luna Lake	Apache
Lyman Lake	Apache
Lake Mohave	Mohave (Clark in NV)
Lake Pleasant	Yavapai, Maricopa
Lake Powell	Coconino (Kane, Garfield, San Juan in UT)
Rainbow Lake	Navajo
Theodore Roosevelt Lake	Gila
San Carlos Reservoir	Graham, Gila, Pinal


LYMAN LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
Scale
LYMAN LAKE
ARIZONA
NEW MEXICO
Springerville
Ariz.
N. Mex.
Map Location


109°22'
109°20'
34°22'
34°20'
Little Colorado River outlet
Lyman Canal
dam
A1
B1
C1
A2
Little Colorado River
LYMAN LAKE
Tributary Sampling Site
Lake Sampling Site
0 1 2 Km.
0 1 Mi.
Scale
Ariz.
Map Location

REPORT ON LYMAN LAKE, ARIZONA

STORET NO. 0405

I. CONCLUSIONS

A. Trophic Condition:*

Survey data indicate that Lyman Lake is eutrophic, i.e., nutrient rich and potentially highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a values in the lake ranged from 1.3 µg/l in April to 4.5 µg/l in October, with a mean of 2.6 µg/l. Potential for primary productivity as measured by algal assay control yield was high. Of the 11 Arizona lakes sampled, only 1 had higher median total phosphorus levels (0.099 mg/l), 6 had higher median inorganic nitrogen values (0.060 mg/l), and 1 had higher median orthophosphorus levels (0.056 mg/l) than Lyman Lake.

Survey limnologists did not note any phytoplankton blooms or widespread macrophytes. However, it was noted that the lake was highly turbid on all sampling occasions, and low Secchi disc transparencies (range of 0.2 to 0.8 meters) probably indicate that primary productivity in the lake is light limited.

*See Appendix E.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Lyman Lake was limited by available nitrogen levels during the assay sample collection times (04/30/75, 10/06/75). The lake data substantiate primary limitation by nitrogen throughout the sampling year.

C. Nutrient Controllability:

1. Point sources -

There was one known point source, the Springerville-Eager plant, impacting Lyman Lake during the sampling year. The plant was estimated to contribute 14.6% of the total phosphorus load to Lyman Lake. This annual contribution may be somewhat overestimated since plant operators state that a portion of the discharges from the Springerville plant are diverted and used for irrigation purposes; however, the State of Arizona considers the plant as a significant discharger, and states that continued discharge from this overloaded facility will result in deterioration of stream water quality and possible health hazards (Arizona Department of Health Services, 1976).

The present phosphorus loading of 1.72 g $P/m^2/yr$ is five times that proposed by Vollenweider (1975) as a "eutrophic" loading. However, Vollenweider's model probably is not applicable to lakes in which epilimnetic light penetration is

severely reduced by the presence of suspended materials in the surface waters. In Lyman Lake, primary production as roughly estimated by chlorophyll a levels, was considerably lower than would be expected based upon nutrient levels. The likely reason for this is the inability to develop phytoplankton levels to potential due to light limitation caused by suspended sediments in the water column.

2. Nonpoint sources - Nonpoint sources, including precipitation, contributed all of the calculated phosphorus loading to Lyman Lake during the sampling year. The Little Colorado River contributed 80.0% of the total phosphorus load, and ungaged drainage areas contributed an estimated 4.4% of the total.

The phosphorus export rate of the Little Colorado River (5 kg/km^2/yr) compares favorably with the unimpacted tributary rate of nearby Luna Lake* (6 kg/km^2/yr), and Fools Hollow Lake* (1 kg/km^2/yr).

*See Working Paper Nos. 727 and 729.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry data were provided by Ned Rathbun (1974); average surface area and maximum volume are indicated. Tributary flow data were provided by the Arizona District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 5.67 km^2.
2. Mean depth: 6.7 meters.
3. Maximum depth: 17.4 meters.
4. Volume: 38.238 x 10^6 m^3.
5. Mean hydraulic retention time: 868 days (2.4 years).

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area (km^2)	Mean Flow (m^3/sec)
A-2 Little Colorado River	1,934.7	0.73
Minor tributaries and immediate drainage -	105.7	0.07
Total	2,040.4	0.80

2. Outlets -

A-1 Little Colorado River	2,046.1	0.14
B-1 Lyman Canal	0.0	0.37
Total	2,046.1	0.51

C. Precipitation:

1. Year of sampling: 32.0 cm.

2. Mean annual: 28.8 cm.

III. LAKE WATER QUALITY SUMMARY

Lyman Lake was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake and from a number of depths at each station (see maps, pages v, vi). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 9.8 meters at Station 01, 8.8 meters at Station 02, and 3.4 meters at Station 03. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

...N LAKE
...RET CODE 0405

A. PHYSICAL AND CHEMICAL CHARACTERISTICS

PARAMETER	N*	(4/30/75) S*** = 3 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)	N*	(6/19/75) S*** = 3 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)	N*	(10/ 6/75) S*** = 3 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)
TEMPERATURE (DEG CENT)												
0.-1.5 M DEPTH	5	10.7- 12.1	11.3	0.0- 1.5	6	16.2- 16.6	16.3	0.0- 1.5	6	17.5- 18.6	17.9	0.0- 1.5
MAX DEPTH**	3	9.8- 10.4	10.0	3.0- 9.4	3	14.8- 15.3	15.0	3.4- 9.8	3	17.4- 17.6	17.4	3.0- 9.1
DISSOLVED OXYGEN (MG/L)												
0.-1.5 M DEPTH	5	6.0- 8.0	8.0	0.0- 1.5	6	6.8- 7.2	7.0	0.0- 1.5	6	6.8- 8.0	7.3	0.0- 1.5
MAX DEPTH**	3	7.6- 8.0	7.8	3.0- 9.4	3	6.2- 6.8	6.6	3.4- 9.8	3	7.0- 7.6	7.4	3.0- 9.1
CONDUCTIVITY (UMHOS)												
0.-1.5 M DEPTH	0	***** - *****	*****	***** - *****	6	307.- 313.	308.	0.0- 1.5	6	303.- 318.	308.	0.0- 1.5
MAX DEPTH**	0	***** - *****	*****	***** - *****	3	302.- 304.	304.	3.4- 9.8	3	304.- 318.	307.	3.0- 9.1
PH (STANDARD UNITS)												
0.-1.5 M DEPTH	5	8.5- 8.6	8.6	0.0- 1.5	6	8.4- 8.5	8.4	0.0- 1.5	6	8.5- 8.6	8.6	0.0- 1.5
MAX DEPTH**	2	8.6- 8.6	8.6	7.9- 9.4	3	8.3- 8.4	8.3	3.4- 9.8	3	8.6- 8.6	8.6	3.0- 9.1
TOTAL ALKALINITY (MG/L)												
0.-1.5 M DEPTH	5	128.- 196.	182.	0.0- 1.5	6	160.- 164.	161.	0.0- 1.5	6	165.- 171.	169.	0.0- 1.5
MAX DEPTH**	2	171.- 197.	184.	7.9- 9.4	3	162.- 163.	162.	3.4- 9.8	3	162.- 171.	169.	3.0- 9.1
TOTAL P (MG/L)												
0.-1.5 M DEPTH	5	0.083-0.185	.090	0.0- 1.5	6	0.102-0.129	0.110	0.0- 1.5	6	0.084-0.150	0.090	0.0- 1.5
MAX DEPTH**	2	0.082-0.116	0.099	7.9- 9.4	3	0.104-0.134	0.128	3.4- 9.8	3	0.093-0.105	0.104	3.0- 9.1
DISSOLVED ORTHO P (MG/L)												
0.-1.5 M DEPTH	5	0.033-0.050	0.037	0.0- 1.5	6	0.058-0.064	0.060	0.0- 1.5	6	0.049-0.057	0.054	0.0- 1.5
MAX DEPTH**	2	0.032-0.036	0.034	7.9- 9.4	3	0.059-0.063	0.062	3.4- 9.8	3	0.054-0.057	0.056	3.0- 9.1
NO2+NO3 (MG/L)												
0.-1.5 M DEPTH	5	0.020-0.060	0.020	0.0- 1.5	6	0.060-0.070	0.070	0.0- 1.5	6	0.020-0.020	0.020	0.0- 1.5
MAX DEPTH**	2	0.030-0.040	0.035	7.9- 9.4	3	0.070-0.080	0.080	3.4- 9.8	3	0.020-0.020	0.020	3.0- 9.1
AMMONIA (MG/L)												
0.-1.5 M DEPTH	5	0.020-0.040	0.030	0.0- 1.5	6	0.050-0.080	0.065	0.0- 1.5	6	0.020-0.020	0.020	0.0- 1.5
MAX DEPTH**	2	0.040-0.050	0.045	7.9- 9.4	3	0.060-0.070	0.060	3.4- 9.8	3	0.020-0.020	0.020	3.0- 9.1
KJELDAHL N (MG/L)												
0.-1.5 M DEPTH	5	0.400-0.700	0.500	0.0- 1.5	6	0.300-0.700	0.400	0.0- 1.5	6	0.200-0.200	0.200	0.0- 1.5
MAX DEPTH**	2	0.400-0.400	0.400	7.9- 9.4	3	0.300-0.400	0.400	3.4- 9.8	3	0.200-0.200	0.200	3.0- 9.1
SECCHI DISC (METERS)												
	3	0.2- 0.3	0.3		3	0.2- 0.3	0.3		3	0.5- 0.8	0.6	

* N = NO. OF SAMPLES
** MAXIMUM DEPTH SAMPLED AT EACH SITE
*** S = NO. OF SITES SAMPLED ON THIS DATE

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units Per ml
04/30/75	1. Cryptomonas	62
	2. Cocconeis	31
	3. Nitzschia	31
	4. Phacus	31
	Other genera	---
	Total	155
06/19/75	1. Chroomonas?	234
	2. Stephanodiscus	39
	Other genera	---
	Total	273
10/06/75	1. Chroococcus	276
	2. Chroomonas?	184
	3. Stephanodiscus	46
	4. Cryptomonas	46
	5. Anabaena	46
	Other genera	45
	Total	643

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/30/75	01	1.3
	02	1.3
	03	1.8
06/19/75	01	2.5
	02	2.4
	03	3.7
10/06/75	01	4.5
	02	3.5
	03	2.7

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. 04/30/75

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.045	0.120	8.6
0.05 P	0.095	0.120	7.1
0.05 P + 1.0 N	0.095	1.120	24.5
1.00 N	0.045	1.120	11.7

b. 10/06/75

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.055	0.095	5.8
0.05 P	0.105	0.095	5.9
0.05 P + 1.0 N	0.105	1.095	40.6
1.00 N	0.055	1.095	25.4

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum*, indicate that the potential for primary productivity in Lyman Lake was high at both sample collection times (04/30/75, 10/06/75). In both assays a significant increase in yield over that of the control occurred when nitrogen was added alone and in combination with phosphorus, indicating nitrogen limitation. The addition of only phosphorus resulted in yields which were not significantly greater than that of the control.

The mean inorganic nitrogen to orthophosphorus ratios (N/P) in the lake data were approximately 2/1 in the spring and summer and 1/1 in the fall, further suggesting primary limitation by nitrogen (a mean N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

*For further information regarding the algal assay test procedure and selection of test organisms, see U.S. EPA (1971).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Arizona National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the maps (pages v, vi), except for the high runoff months of April and May when two samples were collected. Sampling was begun in December 1974, and was completed in November 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Arizona District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in kg/km^2/year in the Little Colorado River, at Station A-2, and multiplying the means by the ZZ area in km^2.

Nutrient loads for the Springerville-Eager wastewater treatment plant were estimated using provided monthly effluent samples and estimated flows.

A. Waste Sources:

1. Known municipal -

Name	Pop.* Served	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Springerville-Eager	1,750	Stabilization Pond	0.662**	Nutrioso Creek

2. Known industrial - None

*Provided by treatment plant operator.
**Estimated at 0.785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Little Colorado River	7,775	80.0
b. Minor tributaries and immediate drainage (nonpoint load) -	425	4.4
c. Known municipal STP's -		
Springerville-Eager	1,425	14.6
d. Septic tanks* -	<5	<0.1
e. Known industrial - None		
f. Direct precipitation** -	100	1.0
Total	9,725	100.0

2. Outputs -

A-1 Little Colorado River	545
B-1 Lyman Canal	2,900
Total	3,445

3. Net annual P accumulation - 6,280

*Estimate based on 1 park.
**Estimated (See NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Little Colorado River	36,225	75.6
b. Minor tributaries and immediate drainage (nonpoint load) -	2,010	4.2
c. Known municipal STP's -		
Springerville-Eager	3,535	7.4
d. Septic tanks* -	35	0.1
e. Known industrial - None		
f. Direct precipitation** -	6,120	12.7
Total	47,925	100.0

2. Outputs -

A-1 Little Colorado River	5,890	
B-1 Lyman Canal	37,200	
Total	43,090	

3. Net annual N accumulation - 4,835

*Estimate based on 1 park.
**Estimated (See NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Little Colorado River	4	19

E. Yearly Loading:

In the following table, the existing phosphorus loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading (g/m^2/yr)
Estimated loading for Lyman Lake	1.72
Vollenweider's "eutrophic" loading	0.33
Vollenweider's "oligotrophic" loading	0.16

V. LITERATURE REVIEWED

Arizona Department of Health Services. 1976. Water Quality Management Basin Plan, Little Colorado River Basin, Arizona. Phoenix, Arizona.

Rathbun, Ned L. 1974. Personal Communication (lake morphometry). Arizona Game and Fish Department, Phoenix, Arizona.

U.S. Environmental Protection Agency. 1971. Algal Assay Procedure Bottle Test. National Eutrophication Research Program, Corvallis, Oregon.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR ARIZONA 11/26/76

LAKE CODE 0405 LYMAN

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 2046.1

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ME
0405A1	2046.1	0.011	0.006	0.014	0.283	0.850	0.113	0.127	0.113	0.071	0.014	0.014	0.011	0.1
0405A2	1934.7	0.34	0.37	0.91	3.11	1.42	0.40	0.34	0.71	0.40	0.25	0.23	0.31	0.
040581	0.0	0.006	0.006	0.006	0.425	0.850	0.850	0.850	0.991	0.425	0.0	0.0	0.003	0.3
0405Z2	111.4	0.023	0.042	0.085	0.283	0.227	0.042	0.014	0.014	0.028	0.057	0.028	0.014	0.0

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 2046.1
SUM OF SUB-DRAINAGE AREAS = 2046.1

TOTAL FLOW IN = 14.05
TOTAL FLOW OUT = 1.03

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
0405A1	12	74	0.006	8	0.007				
	1	75	0.005						
	2	75	0.006	1	0.006				
	3	75	0.006	8	0.006				
	4	75	0.008	5	0.003	18	0.006		
	5	75	0.083	2	0.051	18	0.096		
	6	75	0.116	15	0.136				
	7	75	0.148	16	0.153				
	8	75	0.120	16	0.119				
	9	75	0.049	11	0.034				
	10	75	0.018	13	0.017				
	11	75	0.023	15	0.025				
0405A2	12	74	0.133	8	0.150				
	1	75	0.084						
	2	75	0.213	1	0.136				
	3	75	0.966	8	0.204				
	4	75	4.106	5	1.642	18	2.775		
	5	75	2.481	2	7.079	18	2.152		
	6	75	0.544	15	0.425				
	7	75	0.566	16	0.396				
	8	75	0.255	16	0.272				
	9	75	0.733	11	1.048				
	10	75	0.114	13	0.108				
	11	75	0.126	15	0.136				

TRIBUTARY FLOW INFORMATION FOR ARIZONA 11/26/76

LAKE CODE 0405 LYMAN

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
040591	12	74	0.0	8	0.0				
	1	75	0.0						
	2	75	0.0	1	0.0				
	3	75	0.0	8	0.0				
	4	75	0.070	5	0.0	18	0.0		
	5	75	0.796	2	0.481	18	0.708		
	6	75	0.866	15	0.708				
	7	75	0.980	16	0.595				
	8	75	1.042	16	1.189				
	9	75	0.430	11	0.481				
	10	75	0.0	13	0.0				
	11	75	0.0	15	0.0				
040577	12	74	0.014						
	1	75	0.014						
	2	75	0.068						
	3	75	0.170						
	4	75	0.425						
	5	75	0.227						
	6	75	0.014						
	7	75	0.014						
	8	75	0.006						
	9	75	0.057						
	10	75	0.028						
	11	75	0.028						

APPENDIX C

PHYSICAL AND CHEMICAL DATA

STORET RETRIEVAL DATE 76/11/26
NATL EUTROPHICATION SURVEY
EPA-LAS VEGAS

040501
34 22 23.0 109 22 45.0 3
LYMAN LAKE
04001 ARIZONA

11EPALES 760109 2111202
0035 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/04/30	14	35 0000	12.1	6.0	13		8.50	196	0.030	0.700	0.020	0.037
	14	35 0005	10.7	6.0			8.50	196	0.020	0.400	0.020K	0.033
	14	35 0015	9.9	8.2			8.60	195	0.030	0.500	0.020K	0.033
	14	35 0031	9.8	8.0			8.60	197	0.040	0.400	0.040	0.032
75/06/19	11	20 0000	16.6	7.2	12	313	8.50	162	0.080	0.700	0.070	0.060
	11	20 0005	15.4	7.0		307	8.45	161	0.060	0.400	0.060	0.062
	11	20 0015	15.7	6.8		304	8.40	162	0.070	0.400	0.070	0.059
	11	20 0032	14.5	6.2		304	8.30	162	0.060	0.300	0.040	0.059
75/10/06	14	30 0000	17.5	7.4	24	306	8.55	169	0.020K	0.200K	0.020K	0.049
	14	30 0005	17.5	7.6		303	8.60	169	0.020K	0.200K	0.020K	0.053
	14	30 0015	17.5	7.6		303	8.60	170	0.020K	0.200K	0.020K	0.056
	14	30 0030	17.4	7.6		307	8.60	169	0.020K	0.200K	0.020K	0.057

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/04/30	14	35 0000	0.087	1.3	
	14	35 0005	0.083		
	14	35 0015	0.081		
	14	35 0031	0.082		
75/06/19	11	20 0000	0.105	2.5	
	11	20 0005	0.116		
	11	20 0015	0.095		
	11	20 0032	0.104		
75/10/06	14	30 0000	0.087	4.5	
	14	30 0005	0.089		
	14	30 0015	0.094		
	14	30 0030	0.105		

K VALUE KNOWN TO BE LESS THAN INDICATED

APPENDIX C PHYSICAL AND CHEMICAL DATA

STORET RETRIEVAL DATE 76/11/26
NATL EUTROPHICATION SURVEY
EPA-LAS VEGAS

040502
34 21 40.0 109 21 40.0 3
LYMAN LAKE
04001 ARIZONA

11EPALES 760109 2111202
0630 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/04/30	15 00	0000	11.3	7.8	12		8.60	182	0.030	0.500	0.030	0.036
	15 00	0005	11.2	8.0			8.60	180	0.030	0.400	0.020	0.037
	15 00	0015	10.1	8.0			8.65	173	0.040	0.400	0.030	0.038
	15 00	0026	10.0	7.6			8.65	171	0.050	0.400	0.030	0.036
75/06/19	11 50	0000	16.3	7.2	9	308	8.40	161	0.060	0.500	0.060	0.059
	11 50	0005	16.2	6.8		308	8.40	161	0.080	0.300	0.070	0.060
	11 50	0015	15.6	6.8		301	8.40	160	0.090	0.400	0.080	0.062
	11 50	0029	15.0	6.6		302	8.35	162	0.070	0.400	0.080	0.062
75/10/06	14 50	0000	18.1	8.0	30	309	8.60	171	0.020K	0.200K	0.020K	0.054
	14 50	0005	17.8	7.2		304	8.60	171	0.020K	0.200K	0.020K	0.056
	14 50	0015	17.6	7.2		303	8.60	169	0.020K	0.200K	0.020K	0.055
	14 50	0023	17.4	7.4		318	8.60	171	0.020K	0.200K	0.020K	0.054

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/04/30	15 00	0000	0.094	1.3	
	15 00	0005	0.090		
	15 00	0015	0.094		
	15 00	0026	0.116		
75/06/19	11 50	0000	0.105	2.4	
	11 50	0005	0.102		
	11 50	0015	0.112		
	11 50	0029	0.134		
75/10/06	14 50	0000	0.084	3.5	
	14 50	0005	0.150		
	14 50	0015	0.084		
	14 50	0023	0.104		

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 76/11/26
NATL EUTROPHICATION SURVEY
EPA-LAS VEGAS

040503
34 21 12.0 109 20 45.0 3
LYMAN LAKE
04001 ARIZONA

11EPALES 760109 211120C
0014 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/04/30	15 25 0000		11.4	8.0	9		8.60	128	0.040	0.500	0.060	0.050
	15 25 0010		10.4	7.8								
75/06/19	12 15 0000		16.3	6.8	11	308	8.40	164	0.050	0.400	0.070	0.058
	12 15 0005		16.2	7.0		307	8.40	160	0.070	0.400	0.070	0.064
	12 15 0011		15.3	6.8		304	8.40	163	0.060	0.400	0.070	0.063
75/10/06	15 10 0000		16.6	6.8	18	318	8.60	165	0.020K	0.200	0.020K	0.057
	15 10 0005		16.3	7.0		313	8.60	168	0.020K	0.200K	0.020K	0.055
	15 10 0010		17.6	7.0		304	8.60	162	0.020K	0.200K	0.020K	0.056

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/04/30	15 25 0000		0.185	1.8	
75/06/19	12 15 0000		0.126	3.7	
	12 15 0005		0.129		
	12 15 0011		0.128		
75/10/06	15 10 0000		0.091	2.7	
	15 10 0005		0.099		
	15 10 0010		0.093		

K VALUE KNOWN TO BE LESS THAN INDICATED

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 76/11/30
NATL EUTROPHICATION SURVEY
EPA- LAS VEGAS

0405A1
34 22 05.0 109 22 56.0 4
LITTLE COLORADO RIVER
04 7.5 LYMAN LK SW
0/LYMAN LAKE 110591
PAVED RD BRDG BELOW LYMAN DAM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/12/08	09 30		0.024	1.200	0.010	0.045	0.110
75/02/01	09 20		0.008	1.600	0.016	0.048	0.160
75/03/08	09 25		0.015	1.200	0.022	0.045	0.070
75/04/05	07 10		0.015	0.600	0.020	0.040	0.110
75/04/18	16 35		0.005	1.250	0.030	0.035	0.130
75/05/02	13 05		0.020	0.550	0.020	0.025	0.100
75/05/18	10 00		0.040	0.950	0.030	0.055	0.110
75/06/15	11 05		0.070	1.250	0.035	0.080	0.290
75/07/16	11 15		0.145	0.900	0.115	0.100	0.180
75/08/16	11 20		0.065	1.200	0.025	0.070	0.160
75/09/11	09 20		0.045	0.600	0.055	0.070	0.160
75/10/13	14 30		0.020	2.000	0.045	0.065	0.220
75/11/15	11 05		0.020	1.700	0.030	0.055	0.080

STORET RETRIEVAL DATE 76/11/30
NATL EUTHOPHICATION SURVEY
EPA- LAS VEGAS

0405A2
34 20 55.0 109 20 03.0 4
LITTLE COLORADO RIVER
04 7.5 LYMAN LAKE
T/LYMAN LAKE 110591
BNK 300 FT SW RD 2.5 M E RT 180/666 JCT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/12/08	08 30		0.008	0.800	0.035	0.090	0.150
75/02/01	08 30		0.008	0.800	0.060	0.112	0.170
75/03/08	09 00		0.012	1.450	0.024	0.128	0.270
75/04/05	06 45		0.010	0.800	0.010	0.075	0.300
75/04/18	16 05		0.030	3.600	0.180	0.080	0.690
75/05/02	11 15		0.050	1.950	0.045	0.065	0.830
75/05/18	09 40		0.020	2.100	0.025	0.075	0.190
75/06/15	10 45		0.005	1.480	0.025	0.080	0.135
75/07/16	10 45		0.085	0.800	0.050	0.210	0.400
75/08/16	11 40		0.005	1.800	0.025	0.175	0.360
75/09/11	08 50		0.090	1.500	0.040	0.120	0.500
75/10/13	13 40		0.005	1.500	0.015	0.075	0.150
75/11/15	10 40		0.005	0.800	0.005	0.060	0.120

STORET RETRIEVAL DATE 76/11/30
NATL EUTROPHICATION SURVEY
EPA- LAS VEGAS

040581
34 19 50.0 109 21 18.0 4
LYMAN CANAL
04 7.5 LYMAN LK SW
0/LYMAN LAKE 110591
BNK OFF PVD RD .4 M NNE RT 180/666 JCT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/05/02	13	10	0.020	0.625	0.025	0.025	0.115
75/05/18	10	05	0.035	1.400	0.045	0.055	0.110
75/06/15	11	10	0.070	1.800	0.045	0.070	0.280
75/07/16	11	20	0.150	0.500	0.045	0.100	0.190
75/09/11	09	35	0.045	0.800	0.045	0.070	0.180

STORET RETRIEVAL DATE 76/11/30
NATL EUTROPHICATION SURVEY
EPA- LAS VEGAS

0405XA PD0405XA P001750
34 08 00.0 109 17 00.0 4
SPRINGERVILLE
04 7.5 SPRINGERVILL
T/LYMAN LAKE 110591
NUTRIOSO CREEK
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/03/31	09	30	0.185	12.000	0.510	4.200	4.500		
75/04/30	11	00	0.200	21.000	0.200	5.400	8.100		
75/06/27	09	30	0.250	7.300	0.055	2.300	3.300		
75/07/31	07	00	0.075	9.800	0.043	3.500	4.400		
75/08/27	11	00	0.125	11.000	0.075	2.800	3.900		
75/09/30	08	00	0.275	12.500	0.140	2.700	4.200		
75/10/28	07	30	0.325	18.000	1.450	4.200	7.200		
75/11/25	07	30	0.190	24.000	10.000	6.275	7.300		
75/12/29	08	30	14.000	3.600	0.033	5.700	6.400		
76/01/26	07	45	0.500	2.100	0.057		6.900		
76/02/25	08	00	15.500	3.400	0.025	6.200	7.100		
76/03/24	08	30	0.025	19.000	0.250	4.700	7.400		

APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1975

STATE OF ARIZONA

Mean or median values for six of the key parameters evaluated in establishing the trophic conditions of Arizona lakes sampled are presented to allow direct comparison of the ranking, by parameter, of each lake relative to the others. Median total phosphorus, median inorganic nitrogen and median dissolved orthophosphorus levels are expressed in mg/l. Chlorophyll *a* values are expressed in µg/l. To maintain consistent rank order with the preceding parameters, the mean Secchi disc depth, in inches, is subtracted from 500. Similarly, minimum dissolved oxygen values are subtracted from 15 to create table entries.

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
0401	BIG LAKE	0.032	0.090	386.000	2.900	9.000	0.007
0402	FOOLS HOLLOW	0.059	0.090	466.600	10.683	14.800	0.014
0403	LAKE HAVASU	0.015	0.170	420.231	3.948	10.800	0.005
0404	LUNA LAKE	0.182	0.050	396.250	3.400	12.200	0.131
0405	LYMAN LAKE	0.099	0.060	484.667	2.633	9.000	0.056
0406	LAKE MOHAVE	0.017	0.240	369.667	4.404	8.600	0.010
0407	LAKE PLEASANT	0.027	0.040	449.154	9.808	14.900	0.004
0408	LAKE POWELL	0.009	0.400	239.000	1.333	12.200	0.010
0409	RAINBOW LAKE	0.046	0.045	440.750	16.367	12.000	0.009
0410	ROOSEVELT LAKE	0.020	0.040	429.917	4.073	14.000	0.008
0411	SAN CARLOS RESERVOIR	0.056	0.060	474.500	14.750	14.600	0.009
3201	LAKE MEAD	0.020	0.505	453.600	1.150	8.000	0.007

34

33 BLANK

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
0401	BIG LAKE	45 (5)	41 (4)	82 (9)	73 (8)	77 (8)	73 (8)
0402	FOOLS HOLLOW	18 (2)	41 (4)	18 (2)	18 (2)	9 (1)	18 (2)
0403	LAKE HAVASU	91 (10)	27 (3)	64 (7)	55 (6)	64 (7)	91 (10)
0404	LUNA LAKE	0 (0)	73 (8)	73 (8)	64 (7)	41 (4)	0 (0)
0405	LYMAN LAKE	9 (1)	64 (7)	0 (0)	82 (9)	77 (8)	9 (1)
0406	LAKE MOHAVE	82 (9)	18 (2)	91 (10)	36 (4)	91 (10)	32 (3)
0407	LAKE PLEASANT	55 (6)	95 (10)	36 (4)	27 (3)	0 (0)	100 (11)
0408	LAKE POWELL	100 (11)	9 (1)	100 (11)	91 (10)	41 (4)	32 (3)
0409	RAINBOW LAKE	36 (4)	82 (9)	45 (5)	0 (0)	55 (6)	45 (5)
0410	ROOSEVELT LAKE	68 (7)	95 (10)	55 (6)	45 (5)	27 (3)	64 (7)
0411	SAN CARLOS RESERVOIR	27 (3)	55 (6)	9 (1)	9 (1)	18 (2)	55 (6)
3201	LAKE MEAD	68 (7)	0 (0)	27 (3)	100 (11)	100 (11)	82 (9)